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⑷ Applicant: DAIKIN INDUSTRIES, LIMITED  
Umeda Center Building 4-12 Nakazaki-nishi  
2-chome Kita-ku  
Osaka 530(JP)

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⑵ Inventor: INUKAI, Hiroshi  
8-11-710, Showaen  
Settsu-shi Osaka 566(JP)  
Inventor: YASUHARA, Takashi  
2-21-21, Hitotsuya  
Settsu-shi Osaka 566(JP)  
Inventor: KITAHARA, Takahiro  
C-22 101, 1-ban Tsukumodai 2-chome  
Suita-shi Osaka 565(JP)

㉑ Designated Contracting States:  
DE FR GB

㉒ Representative: Schüller, Horst, Dr.  
Kaiserstrasse 69  
D-6000 Frankfurt/Main 1(DE)

㉓ **HEXAFLUORONEOPENTYL ALCOHOL, ITS DERIVATIVES, FLUORINATED POLYMERS AND THEIR USE.**

⑤ A1 This invention provides (i) novel hexafluoroneopentyl alcohol, (ii) its derivatives, i.e., hexafluoroneopentyl (meth)acrylate, (iii) fluorinated polymers comprising said acrylate as the monomer component, and (iv) optical materials comprising said fluorinated polymers.

EP 0 364 587 A1

HEXAFLUORONEOPENTYL ALCOHOL, DERIVATIVE THEREOF  
FLUORINE-CONTAINING POLYMER AND ITS USE

Field of the Invention

The present invention relates to a novel  
5 hexafluoroneopentyl alcohol, hexafluoroneopentyl acrylate  
or methacrylate obtained as its derivative, fluorine-  
containing polymer prepared from the derivative and the  
use of the polymer as an optical material.

Prior Art and Its Problems

10 Optical fibers are well known which comprise a  
transparent glass or plastics core and a cladding covering  
the core concentrically therewith to provide a composite  
fiber and having a lower refractive index than the core  
material, such that when light is applied at one end of  
15 the fiber, light travels through the fiber while being  
totally reflected in its interior.

Various polymers have been proposed for use as  
plastics materials for forming a cladding. Of these  
polymers, only a few are fully satisfactory in the  
20 properties of having a high softening temperature and a  
low refractive index which are required of cladding  
materials for optical fibers. Of the few, perfluoro-t-  
butyl methacrylate is disclosed in Japanese Unexamined  
Patent Publication No. 49-129,545 as optical materials  
25 capable of fulfilling said property requirements.

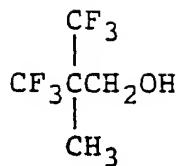
However, perfluoro-t-butyl methacrylate has the drawbacks of having a low flexibility and a poor adhesion to the core.

An object of the present invention is to provide  
5 a novel monomer compound and a starting material for the monomer compound, the monomer compound being capable of giving a polymer which is free of the foregoing drawbacks, namely fully satisfactory in the properties of having a high softening temperature and a low refractive index as  
10 required of cladding materials for optical fibers and excellent in the flexibility and good in the adhesion to the core.

Means for Solving the Problems

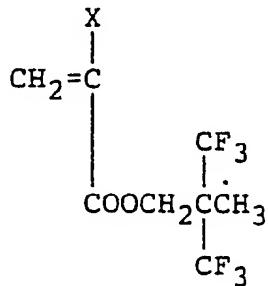
The present inventors discovered that a polymer  
15 prepared from hexafluoroneopentyl acrylate or methacrylate which is a novel monomer compound has a specifically high glass transition temperature (hereinafter referred to as "Tg"), a low refractive index, a great flexibility and a good adhesion to the core and that the hexafluoroneopentyl  
20 acrylate or methacrylate can be easily synthesized from a novel hexafluoroneopentyl alcohol. The present invention has been accomplished based on these novel findings.

According to the present invention, there are provided a hexafluoroneopentyl alcohol represented by the  
25 formula



and hexafluoroneopentyl acrylate or methacrylate

5 represented by the formula

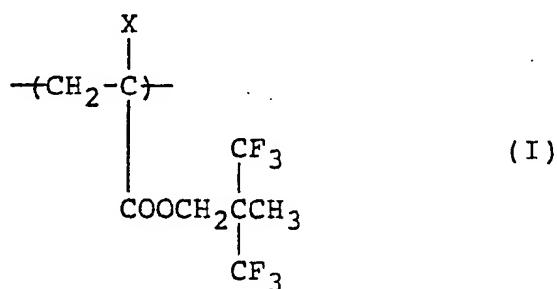


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wherein X represents hydrogen atom, fluorine atom, chlorine atom, bromine atom, iodine atom or methyl group.

15

According to the present invention, there are further provided a fluorine-containing polymer comprising a structural unit represented by the formula



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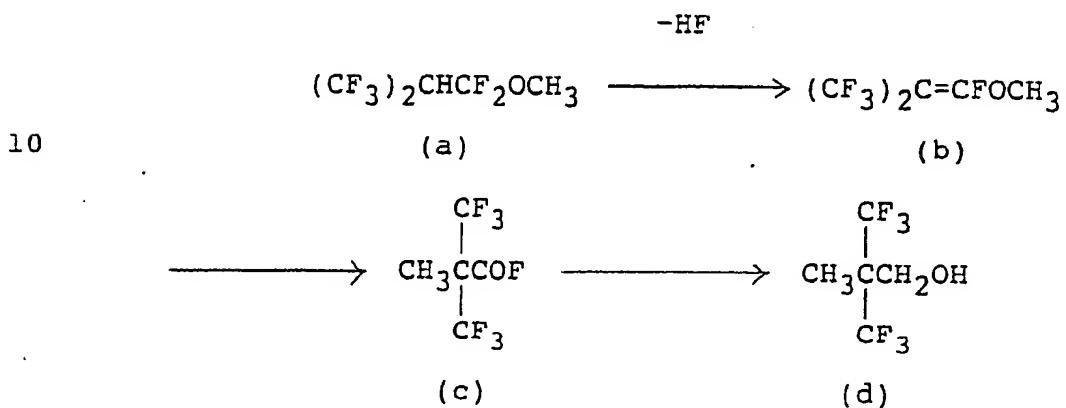
wherein X represents hydrogen atom, fluorine atom, chlorine atom, bromine atom, iodine atom or methyl group, and an optical material prepared from said fluorine-containing polymer.

25

The hexafluoroneopentyl alcohol of this

invention can be prepared by the following process.

First, as illustrated in the following reaction scheme, an adduct of octafluoroisobutene with methanol (a) is subjected to a reaction for removing HF, giving the olefin 5 (b) shown below. The olefin (b) is subjected to rearrangement reaction, giving the acid fluoride (c) shown below which is then subjected to reduction.



15 The foregoing rearrangement reaction is conducted in the presence of a suitable solvent. Examples of preferred solvents are dimethylformamide, dimethylacetamide, etc. The amount of the solvent used is 0.01 to 10 times, preferably 0.1 to 2 times, the amount 20 of the olefin (b). A smaller amount of the solvent used reduces the rate of rearrangement reaction, whereas a larger amount thereof involves a cumbersome treatment of waste and leads to formation of reaction product in a small amount despite the large reaction scale. A 25 preferred reaction temperature is in the range of room

temperature to 100°C.

The reduction from the acid fluoride (c) to the product (d) is carried out using a reducing agent in an organic solvent. Examples of useful organic solvents are 5 diethyl ether, diglyme, tetrahydrofuran, etc. Examples of useful reducing agents are  $\text{LiAlH}_4$ ,  $\text{NaBH}_4$ , etc. The amount of the organic solvent used is 1 to 10 times the amount of the acid fluoride (c) and the amount of the reducing agent used is 0.5 to 5 moles per mole of the acid fluoride 10 (c). A preferred reaction temperature is 40 to 150°C. The reduction may be performed directly by using  $\text{H}_2$ .

The obtained hexafluoroneopentyl alcohol (d) is purified preferably by distillation. The hexafluoroneopentyl alcohol (d) of the invention is in the 15 form of colorless needle-like crystals at room temperature.

Next, the process for preparing the hexa-fluoroneopentyl acrylate or methacrylate of the invention will be described below. The hexafluoroneopentyl acrylate 20 or methacrylate is prepared by one of the following processes (1) to (3) using as the starting compound the hexafluoroneopentyl alcohol given by the foregoing processes; (1) subjecting the hexafluoroneopentyl alcohol to dehydrohalogenation reaction with acrylic or methacrylic acid halide in the presence of a co-acid catalyst such as 25

pyridine, triethylamine or like organic base, (2) subjecting the hexafluoroneopentyl alcohol to dehydration reaction with acrylic or methacrylic acid using a dehydrating agent such as phosphorus pentoxide, sulfuric acid or the like and (3) subjecting the hexafluoroneopentyl alcohol to ester interchange reaction with methyl acrylate or methacrylate.

5 Of the processes (1) to (3), the processes (1) and (2) are more preferred in view of ease of operation and yield. When required, a solvent such as benzene, 10 toluene, dimethylformamide or the like may be used in these reactions. In the process (1), the amount of the co-acid catalyst used is 0.1 to 2 moles per mole of the hexafluoroneopentyl alcohol and a preferred reaction 15 temperature is 0 to 100°C. In the process (2), the amount of the dehydrating agent used is 0.7 to 5 moles per mole of the hexafluoroneopentyl alcohol and a preferred reaction temperature is 50 to 100°C.

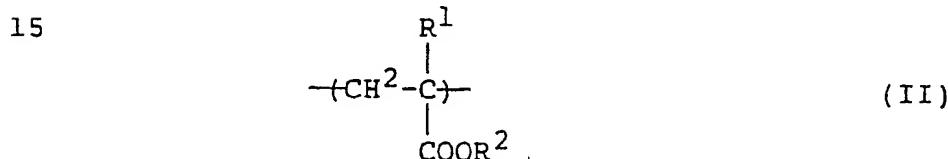
When a readily polymerizable monomer compound is 20 produced, the reaction is done in the presence of a polymerization inhibitor. Useful polymerization inhibitors are not specifically limited insofar as they can inhibit radical polymerization. Examples of such 25 polymerization inhibitors are hydroquinone, hydroquinonemonomethyl ether, tri-tert-butyl phenol, tert-

butyl catechol, phenothiazine, etc.

The hexafluoroneopentyl acrylate or methacrylate of the invention is a colorless, transparent liquid at room temperature.

5           The fluorine-containing polymers of the invention include not only homopolymers having the structural unit of the formula (I) but copolymers containing 10% by weight or more of the structural unit of the formula (I).

10           Examples of preferable copolymers include those comprising 10% by weight or more of the structural unit of the formula (I) and 90 to 0.1% by weight, preferably 70 to 0.1% by weight, more preferably 50 to 0.1% by weight, of a structural unit represented by the formula



wherein  $\text{R}^1$  represents hydrogen atom, fluorine atom or methyl group, and  $\text{R}^2$  represents hydrogen atom, lower alkyl group or fluoroalkyl group.

20           X in the formula (I) is preferably fluorine atom or methyl group. In the formula (II),  $\text{R}^1$  is preferably fluorine atom or methyl group, and  $\text{R}^2$  is preferably aliphatic group such as  $-\text{CH}_3$ ,  $-\text{CH}_2\text{CH}_3$ ,  $-\text{CH}_2\text{CH}_2\text{CH}_3$  and the like, alicyclic hydrocarbon group such as  , 

and the like, and fluoroalkyl group such as  $-\text{CH}_2\text{CF}_3$ ,  $-\text{CH}_2\text{CF}_2\text{CF}_2\text{H}$ ,  $-\text{CH}_2\text{CF}_2\text{CFHCF}_3$ ,  $\text{CH}_2\text{CH}_2\text{C}_8\text{F}_{17}$  and the like.  $\text{R}^2$  may contain functional group such as  $-\text{CH}_2\text{CH}_2\text{OH}$ ,  $-\text{CH}_2\text{CH}_2\text{CH}_2\text{Si}(\text{OCH}_3)_3$ ,  $-\text{H}$ ,  $-\text{CH}_2\text{CHCH}_3$ , etc.

5 The polymer of the invention may be a copolymer prepared by copolymerizing said monomer with other monomers such as styrene, vinyl chloride or the like insofar as such monomers do not impair the characteristics of the resulting copolymer.

10 The fluorine-containing polymer of the invention can be prepared by homopolymerizing the hexafluoroneopentyl acrylate or methacrylate or copolymerizing the monomer with other monomers.

15 The fluorine-containing polymer of the invention is prepared by a usual mode of polymerization such as mass (or bulk) polymerization, solution polymerization, suspension polymerization or emulsion polymerization.

20 Preferred polymerization initiators for use in preparation of the fluorine-containing polymer by mass (or bulk), solution or suspension polymerization are azobisisobutyronitrile, isobutyryl peroxide, octanoyl peroxide, diisopropyl peroxy dicarbonate, fluorine-containing organic peroxides represented by the formula  $[\text{Cl}(\text{CF}_2\text{CFCl})_2\text{CF}_2\text{COO}]_2$ ,  $[\text{X}(\text{CF}_2\text{CF}_2)_n\text{COO}]_2$  and  $[\text{X}(\text{CF}_2\text{CF}_2)_n\text{COO}]_2$  (in the formulae, X is hydrogen, fluorine

or Cl, and n is 1 to 10], etc. Polymerization initiators useful for emulsion polymerization are redox initiators including oxidizing agents such as ammonium persulfate, potassium persulfate and like persulfates, reducing agents such as sodium sulfite, and salts of transition metals such as ferrous sulfate.

5 It is desirable in the mass, solution or suspension polymerization to use a chain transfer agent such as mercaptans in order to provide the novel fluorine-10 containing polymer with a higher thermal decomposition temperature and to adjust the molecular weight distribution. When a chain transfer agent is used, the amount of the agent used is 0.01 to 1 part by weight per 100 parts by weight of the monomer.

15 Typical of the media useful in preparing the novel fluorine-containing polymer of the invention by the solution or suspension polymerization are Freon-12, Freon-113, Freon-114, Freon-C318 and like fluorine-type solutions and hydrocarbon solvents such as butyl acetate, 20 methyl isobutyl ketone and the like.

The polymerization temperature, which is usually in the range of 0 to 100°C, is determined in connection with the decomposition temperature of the polymerization initiator used. Preferably the temperature is 10 to 80°C 25 in most cases.

The polymerization pressure ranges from 0 to 50 kg/cm<sup>2</sup>G.

The fluorine-containing polymers of the invention which can be prepared by the foregoing 5 polymerization reaction are usually about 10,000 to about 5,000,000 in molecular weight (as determined by gel permeation chromatography), about 0.15 to about 3.0 in viscosity [ $\eta$ ] as determined at 35°C with MEK, 1.37 to 1.45 in refractive index ( $n_d^{25}$ ) and 120 to 160°C in glass 10 transition temperature.

The novel fluorine-containing polymers of the invention have a higher glass transition temperature than fluoroalkyl methacrylate polymers usually used as a plastics cladding material for optical fibers and 15 therefore can be used in a situation at a comparatively high temperature, for example in the vicinity of an engine of a vehicle where conventional plastics cladding materials can not be used. With a high decomposition temperature, the polymers of the invention have the 20 further advantage of facilitating control of the temperature for fusing the polymer since a wide range of heating temperature is available in fusing and spinning for production of optical fibers.

Further, the fluorine-containing polymers of the 25 invention have a low refractive index, a high transparency

and a good flexibility, hence excellent as an optical material.

The polymers of the invention have other applications for optical fibers than as the plastics 5 cladding material for optical fibers. For example, the polymers of the invention can be used as a coating agent for preventing reflection of light beams which is applied to the surface of a substrate such as plastics, glass or the like to prevent the undesired glare or light 10 scattering.

In addition to applications as optical materials, the polymers of the invention are also usable as an organic glass and an additive for weather-resistant coating compositions.

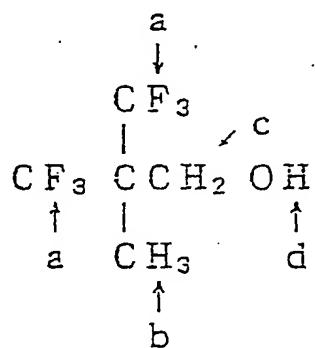
15 Examples

The features of the present invention will be clarified below in more detail with reference to the following Examples and Comparative Examples.

Example 1

20 Into a 1-l, four-necked glass flask equipped with a thermometer, a dropping funnel, a stirrer and a reflux condenser were placed 133.37 g (0.6 mol) of tetraglyme and 15.13 g (0.4 mol) of sodium boron hydride and the mixture was maintained at a temperature of 80°C. 25 To the mixture was added dropwise 106.04 g (0.5 mol) of

2,2-bis(trifluoro)propionic fluoride over a period of 2.5 hours. After addition, the mixture was stirred at 80°C for 3 hours and then cooled to 20°C. Subsequently, 21 cc of hydrochloric acid (35%) was added dropwise thereto and the resulting mixture was washed with 500 cc of water and thereafter distilled at normal pressure, giving 60 g of hexafluoroneopentyl alcohol having a boiling point of 110°C (yield: 60%). The obtained product consisted of colorless, needle-like crystals. The identification was carried out with  $^{19}\text{F}$ -NMR spectrum and  $^1\text{H}$ -NMR spectrum. The spectrum was determined with use of a nuclear magnetic resonance spectrometer (Model FX-100, manufactured by JEOL. Ltd.)



$^{19}\text{F}$ -NMR ( $\text{CF}_3\text{COOH}$  standard)

Na	$\delta$ (p.p.m)
a	7.2

<sup>1</sup>H-NMR (TMS standard)

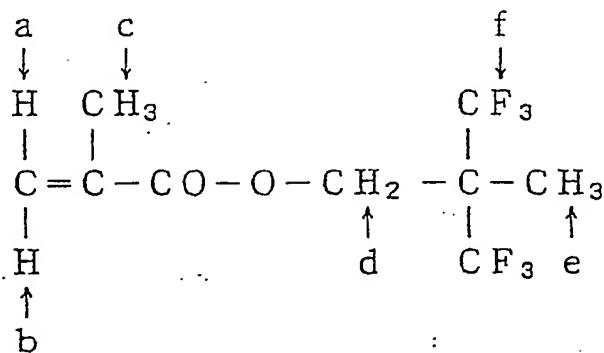
No.	$\delta$ (ppm)
b	1.36
c	3.90
d	3.17

Example 2

Into a 500-ml glass flask were placed 150 g (0.765 mol) of hexafluoroneopentyl alcohol obtained in Example 1, 73 g (0.85 mol) of methacrylic acid and 1 g of t-butyl catechol and the mixture was heated to 70 to 80°C. Then 50 g of diphosphorus pentoxide was added over a period of 2 hours. In this step, the temperature was maintained at 80 to 90°C. After addition, the mixture was further kept at 80 to 90°C for 3 hours to complete the reaction. The reaction mixture was washed with 300 ml of water and the resulting hexafluoroneopentyl methacrylate was distilled under a reduced pressure of 15 mm·Hg. The obtained product had a boiling point of 55°C and a purity, determined by gas chromatography, of 99.9%. The identification was conducted with <sup>1</sup>H-NMR spectrum, <sup>19</sup>F-NMR

spectrum and  $^{13}\text{C}$ -NMR spectrum (in every case, solvent: acetone- $\text{d}_6$ ).

In respect of the compound represented by the formula



there were determined the following chemical shift ( $\delta$ ) and coupling constant (J).

<sup>1</sup>H-NMR (TMS standard)

No.	$\delta$ (ppm)	$J$ (Hz)	coupling form
a	5. 67	—	m
b	6. 16	—	m
c	1. 92	2. 1	d-d
d	4. 50	—	s
e	1. 50	—	s

(Note) s: singlet

d: doublet

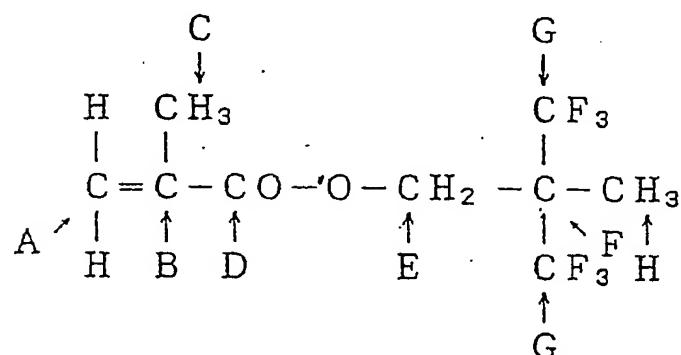
m: multiplet

<sup>19</sup>F-NMR (CF<sub>3</sub>COOH standard)

Low magnetic field: +

No.	$\delta$ (ppm)	J (Hz)	coupling form
f	5.8	—	s

### <sup>13</sup> C - NMR

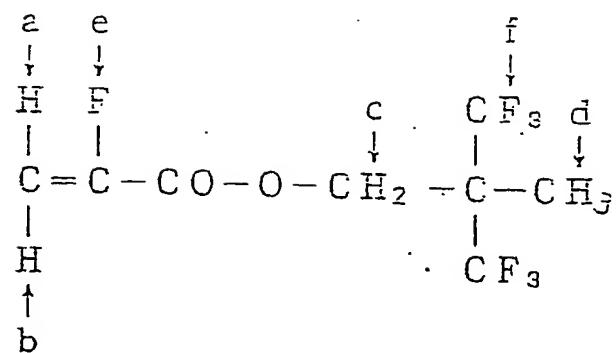


### TMS standard

No.	$\delta$ (ppm)
A	126.3
B	136.0
C	17.7
D	165.80
E	61.3
F	51.1
G	125.3
H	12.2

Example 3

Into a 200-ml, four-necked glass flask provided with a thermometer, a dropping funnel, a stirrer and a reflux condenser were placed 58.83 g (0.3 mol) of hexafluoroneopentyl alcohol, 30.36 g (0.3 mol) of triethylamine and 50 g of chloroform. Subsequently, to the mixture was added dropwise 30.37 g (0.33 mol) of 2-fluoroacrylic fluoride at a temperature of up to 10°C with ice-cooling. After addition, the mixture was stirred at room temperature for 30 minutes. The mixture was washed with an aqueous solution of sodium bicarbonate (5%) and then with pure water, followed by evaporation to remove chloroform, producing hexafluoroneopentyl acrylate. The amount of the obtained product was 67.17 g and the yield was 76.7%. To the product was further added 0.1 g of t-butyl catechol as a polymerization inhibitor and the mixture was distilled under reduced pressure for purification. The boiling point was 55 to 56°C/20 mm.Hg. The identification was performed with  $^1\text{H}$ -NMR spectrum,  $^{19}\text{F}$ -NMR spectrum and  $^{13}\text{C}$ -NMR spectrum (in every case, sovent: acetone- $\text{d}_6$ ).

<sup>1</sup>H-NMR (TMS standard)

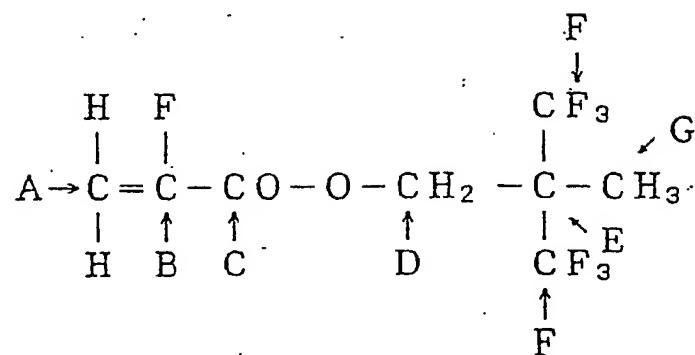
No.	$\delta$ (ppm)
a	5.72
b	5.44
c	4.54
d	1.47

No.	$J$ (Hz)
J a - b	4
J a - e	43
J b - e	13

<sup>19</sup>F-NMR (CF<sub>3</sub>COOH standard)

Low magnetic field: +

No.	$\delta$ (ppm)
e	-40.2
f	+5.9

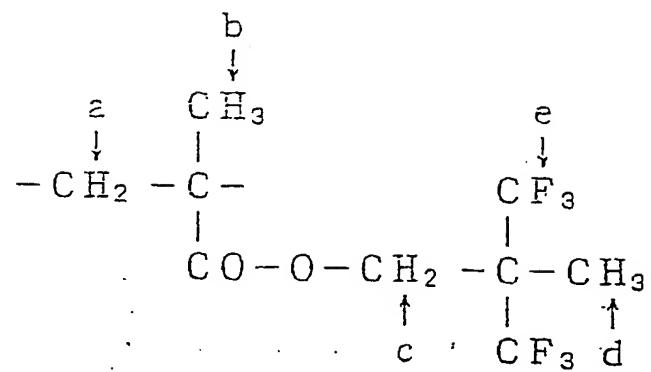
<sup>13</sup>C-NMR

No.	$\delta$ (ppm)
A	103.9
B	153.1
C	159.4
D	62.4
E	51.3
F	125.0
G	12.5

Example 4

Into a 500-ml glass flask were placed 100 parts of hexafluoroneopentyl methacrylate which was purified by distillation under reduced pressure, 0.05 part of n-  
5 dodecyl mercaptan, a polymerization initiator and 0.025 part of 2,2'-azoisobutyronitrile. These substances were mixed for dissolution and a cycle of deaeration and substitution with nitrogen was repeated for hermetically sealing the mixture in the flask.

10 Subsequently, the mixture was polymerized for 16 hours in a reactor maintained at a temperature of 70°C. After completion of the polymerization, to the obtained polymer was added 300 g of acetone for dissolution and the solution obtained was poured into 5 l of methanol. The  
15 precipitated polymer was separated from the liquid and dried at 100°C under reduced pressure for 10 hours to prepare 96.2 g of a polymer (yield: 96%). With respect to molecular weight, the polymer obtained was found to have an inherent viscosity  $[\eta]$  of 0.596 at 35°C using MEK. The  
20 polymer was identified with elemental analysis and nuclear magnetic resonance spectrum. The result of the elemental analysis was C: 40.9, H: 3.8, F: 43.2 and O: 12.1 (%). The nuclear magnetic resonance spectrum was as follows.

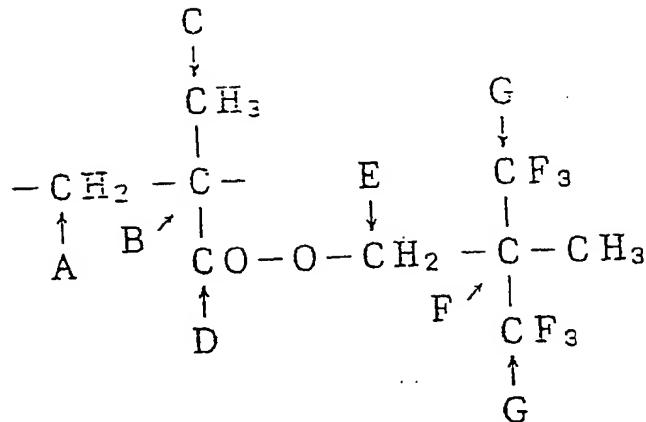


$^1\text{H-NMR}$  (TMS standard)

No.	$\delta$ (ppm)
a	1. 6 - 2. 4
b	1
c	4. 2 6
d	1. 5 5

$^{19}\text{F-NMR}$  ( $\text{CF}_3\text{COOH}$  standard) Low magnetic field: +

No.	$\delta$ (ppm)
e	+6. 4

<sup>13</sup> C-NMR

TMS standard

No.	$\delta$ (ppm)
A	50 - 52
B	45.0
C	16.7, 18.3
D	175.2, 175.9, 176.2
E	6.2.6
F	50.3
G	124.7
H	12.4

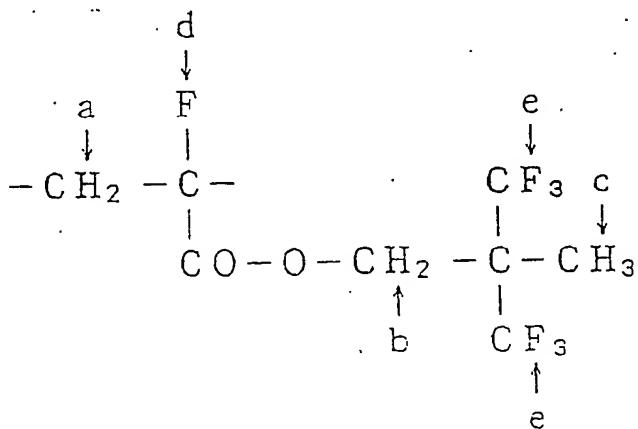
Example 5

Into a 500-ml glass flask were placed 100 parts of hexafluoroneopentyl- $\alpha$ -fluoroacrylate which was purified by distillation under reduced pressure, 0.025 part of n-dodecyl mercaptan, 1.0 part of 2,2'-azobisisobutyronitrile and 233 parts of ethyl acetate serving as a solvent for

polymerization. The aforementioned substances were mixed for dissolution and a cycle of deaeration and substitution with nitrogen was repeated for hermetically sealing the mixture in the flask.

Then the mixture was subjected to polymerization for 18 hours in a reactor maintained at a temperature of 50°C. After completion of the polymerization, the obtained solution of the polymer was poured into 5 l of methanol. The precipitated polymer was separated from the liquid and dried under reduced pressure at 100°C for 10 hours to produce 93 g of a polymer (yield: 93%). In respect of molecular weight, the polymer produced was found to have an inherent viscosity  $[\eta]$  of 0.423 at 35°C using MEK. The identification of the polymer was carried out with elemental analysis and nuclear magnetic resonance spectrum.

The result of the elemental analysis was C: 35.8%, H: 2.6%, F: 49.6% and O: 11.9%. The nuclear magnetic resonance spectrum was as follows.



<sup>1</sup>H-NMR (TMS standard)

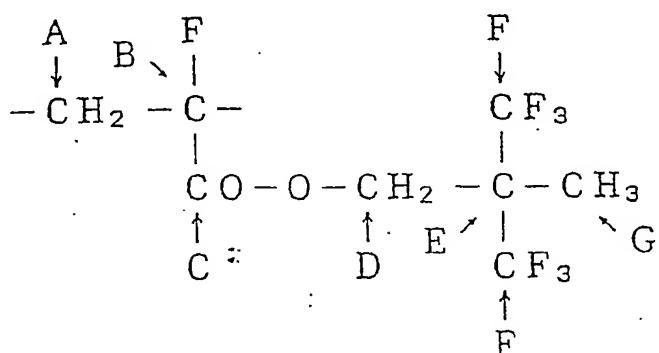
No	$\delta$ (ppm)
$\varepsilon$	2. 0 - 3. 32
b	4. 42
c	1. 54

<sup>19</sup>F-NMR (CF<sub>3</sub>COOH standard)

Low magnetic field: +

No.	$\delta$ (ppm)
d	85.2, 88.8, 93.5
e	-6.2

<sup>13</sup> C-NMR



## TMS standard

No.	$\delta$ (ppm)
A	44.7
B	92.1
C	169.0, 167.9, 166.8
D	62.0
E	50.6
F	124.6
G	11.8

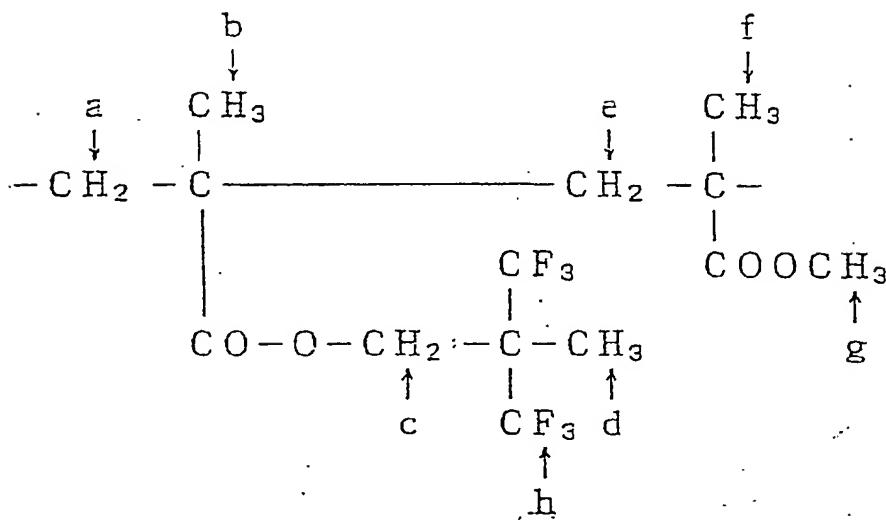
Example 6

Into a 500-ml glass flask were placed 90 parts of hexafluoroneopentyl methacrylate which was purified by distillation under reduced pressure, 10 parts of methyl methacrylate, 0.1 part of n-dodecyl mercaptan and 0.025 part of 2,2'-azobisisobutyronitrile. These substances were mixed for dissolution and the obtained mixture was polymerized in the same manner as in Example 1, giving 98.5 g of a polymer (yield: 98.5%).

In respect of molecular weight, the obtained polymer was found to have an inherent viscosity  $[\eta]$  of 0.494 at 35°C using MEK. Further the identification of the polymer was effected with elemental analysis and nuclear magnetic resonance spectrum.

The result of the elemental analysis was C: 42.8%, H: 4.2%, F: 33.9% and O: 14.1%.

The nuclear magnetic resonance spectrum was as follows.

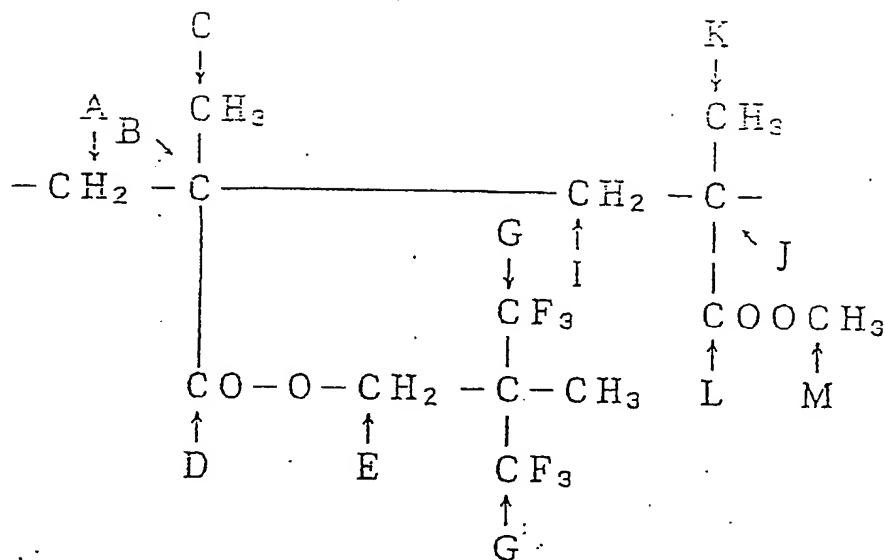


<sup>1</sup>H-NMR (TMS standard)

No.	$\delta$ (ppm)
a, e	1. 6 - 2. 4
b, f	1
c	4. 32
d	1. 60
g	3. 60

<sup>19</sup>F-NMR (CF<sub>3</sub>COOH standard) Low magnetic field: +

No.	$\delta$ (ppm)
h	+ 6. 6

<sup>13</sup> C-NMR

TMS standard

No.	$\delta$ (ppm)
A, I	53.8
B, J	44.6, 44.9
C, K	16.4, 18.3
D, L	175.2 - 177.4
E	62.5
F	50.3
G	124.0
H	12.4
M	51.4

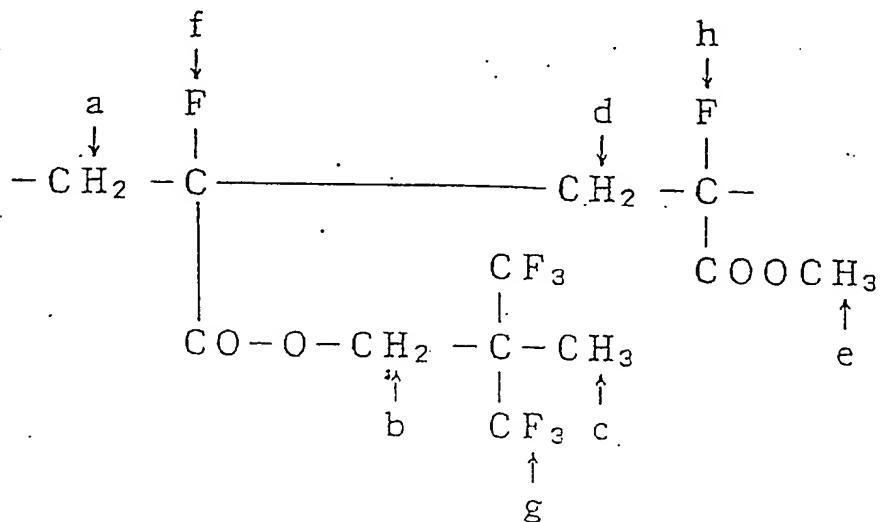
Example 7

Into a 500-ml glass flask were introduced 90 parts of hexafluorocapryloyl- $\alpha$ -fluoroacrylate which was purified by distillation under reduced pressure, 10 parts of methyl- $\alpha$ -fluoroacrylate, 1.0 part of n-dodecyl mercaptan and 0.1 part of 2,2'-azobisisobutyronitrile. These substances were mixed for dissolution and the resulting mixture was polymerized in the same manner as in Example 1 (except that, in this case, the polymerization was conducted at a temperature of 50°C), producing 98.3 g of a polymer (yield: 98.3%).

With regard to molecular weight, the polymer thus obtained was found to have an inherent viscosity  $[\eta]$  of 0.621 at 35°C using MEK.

The result of the elemental analysis was C: 36.85%, H: 2.8%, F: 46.5%, and O: 13.8%.

The nuclear magnetic resonance spectrum was as follows.



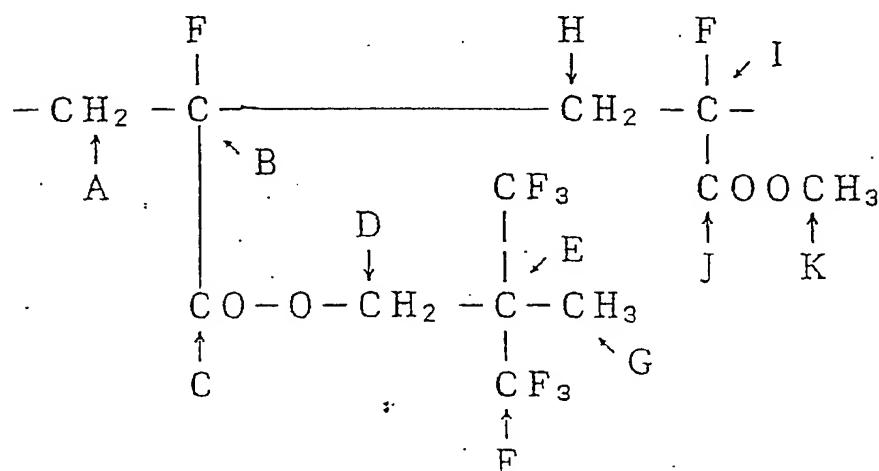
$^1\text{H}$ -NMR (TMS standard)

No	$\delta$ (ppm)
a, d	2. 0 - 3. 34
b	4. 42
c	1. 55
e	3. 70

 $^{19}\text{F}$ -NMR ( $\text{CF}_3\text{COOH}$  standard)

Low magnetic field: +

No.	$\delta$ (ppm)
f, h	85. 2, 88. 8, 93. 4
g	-6. 2

 $^{13}\text{C}$ -NMR

## TMS standard

No	$\delta$ (ppm)
A, H	44.3
B, I	92.1
C, J	169.0, 167.9, 166.8
D	62.0
E	50.6
F	124.6
G	11.8
K	52.2

Comparative Example 1

The polymer of Comparative Example 1 was prepared in the same manner as in Example 4 with the exception of using 2,2,3,3-tetrafluoropropyl methacrylate in place of hexafluoroneopentyl methacrylate.

Comparative Example 2

The polymer of Comparative Example 2 was prepared in the same manner as in Example 4 with the exception of using perfluoro-t-butyl methacrylate in lieu of hexafluoroneopentyl methacrylate.

Test Example 1

The polymers of the present invention as

obtained in Examples 4 to 7 were checked for the following properties. Table 1 shows the results. Properties were evaluated according to the following methods.

(1) Glass transition temperature (Tg)

5           Using a differential scanning calorimeter (Model DSC II, manufactured by Perkin Elmer Co.), the temperature at which the polymer started to absorb heat was determined while elevating the temperature at a rate of 20°C/min.

(2) Decomposition temperature (Tn)

10           Using a differential scanning calorimeter (Model DTG-30, manufactured by Shimadzu Seisakusho, Ltd.), the temperature at which the polymer started to decrease weight was determined while heating the polymer at a temperature elevating rate of 10°C/min.

15           (3) Refractive Index (n<sub>D</sub>)

          Measured at 25°C with use of Abbe refractometer (manufactured by Atago Kogakukiki Mfg. Co., Ltd.).

(4) Melt index (MI)

20           Using a Koka flow tester, manufactured by Shimadzu Seisakusho, Ltd., the fluorine-containing polymer of the present invention was placed into a cylinder having an inside diameter of 9.5 mm, maintained at 230°C for 5 minutes and thereafter extruded through a nozzle having a length of 8 mm and an inside diameter of 2.1 mm under a piston load of 7 kg. The amount in gram of the polymer

extruded for a period of 10 minutes was measured as MI.

(5) Transmission (Tm)

An optical fiber, 300  $\mu\text{m}$  in diameter (15  $\mu\text{m}$  in wall thickness of the cladding material) and 500 mm in 5 length, was conjugate spun at 230°C with use of polymethylmethacrylate as the core material and the fluorine-containing polymer of the invention as the cladding material. The transmission was measured with light 650 to 680 nm in wavelength.

10 (6) Flexibility (Fb)

The fluorine-containing polymer according to the invention was made into a fiber having a diameter of 1 mm by the same method as used for measuring MI. The fiber was wound around round steel rods at room temperature to 15 determine the radius of the rod on which cracks developed in the fiber.

Table 1

Ex. No.	T <sub>g</sub> (°C)	T <sub>n</sub> (°C)	n <sub>D</sub>	M I	T <sub>m</sub> (%)	F <sub>b</sub> (mm)
4	150	286	1.395	30	80	15
5	135		1.37	78	84	<6
6	140	283	1.41	50	75	10
7	150		1.38	33	78	<6

Test Example 2

Even when the polymer obtained in Example 4 was left to stand in an atmosphere at 85°C for 100 hours, there was no decrease in transmission.

Test Example 3

The materials used in Example 6 were dissolved in ethyl acetate to a concentration of 5% by weight and the solution was applied to a PMMA plate (trade name: "Acryptet", product of Mitsubishi Rayon Co., Ltd.) with a doctor blade, 250 µm in length. The coated plate was dried at 80°C for 1 hour to produce a specimen plate. The

thickness of the coat was 8  $\mu\text{m}$ . The properties of the specimen plate were evaluated according to the following test methods.

(1) Reflectance

5 With an UV spectrometer (Model U3200, manufactured by Hitachi, Ltd.) equipped with 5 degrees-specular reflection apparatus, an average reflectance of the coated plate was determined with light of 400 to 700 nm in wavelength.

10 (2) Abrasion resistance

Using a rubbing tester, manufactured by Taihei rika Kabushiki Kaisha, in which a fabric made of Tectoron (brand name of a polyester resin) was set, the coated plate was rubbed with the fabric 1000 times under the 15 weight of 500 g.

(3) Adhesion

Cross-cut/cellophane adhesive tape peeling test was carried out according to JIS K5400.

20 As a result, the reflectance was up to 2.0% and the abrasion resistance was satisfactory.

The coated MMA plate was 85% in transmission with light having a wavelength of 400 to 700 nm. The result of the adhesion (cross-cut) test was 100/100. When the same experiments were conducted at a temperature of 25 80°C, the results were not different.

Comparative Test Example 1

The softening temperature and the decomposition temperature of the polymer of Comparative Example 1 were as low as 72°C and 265°C, respectively and the refractive index was 1.42.

An optical fiber was spun at 250°C with use of the foregoing polymer of Comparative Example 1 as the cladding material and polymethylmethacrylate as the core material to find formation of voids in the cladding. At 10 210°C, spinning could not be effected owing to clogging of nozzle. The optical fiber similar to those obtained in Examples was produced only when the spinning was performed at 230°C, and the transmission of the obtained fiber was 76%. However, the transmission of the fiber was reduced 15 to 52% when the fiber was allowed to stand in an atmosphere at 85°C for 100 hours.

The polymer prepared in Comparative Example 1 was applied to a PMMA plate by the same procedure as in Test Example 3 to produce a specimen plate.

20 The coated plate thus obtained had a reflectance of as low as 2.5% and was found to receive a number of scratches when rubbed 50 times, hence unsatisfactory in abrasion resistance.

25 In the case where the same experiment for checking the abrasion resistance was performed at a

temperature of 80°C, the coated plate was found to receive a lot of scratches when rubbed twice.

Comparative Test Example 2

The polymer of Comparative Example 2 was found, 5 as a result of the measurement, to be not less than 30 nm in flexibility (Fb), hence unusable.

Further, the polymer of the Comparative Example 2 was dissolved in 1,1,2-trichloro-2,2-trifluoroethane to a concentration of 5% and the solution was applied to a 10 PMMA plate in the same manner as in Test Example 3 to form a coat having a thickness of 8 µm.

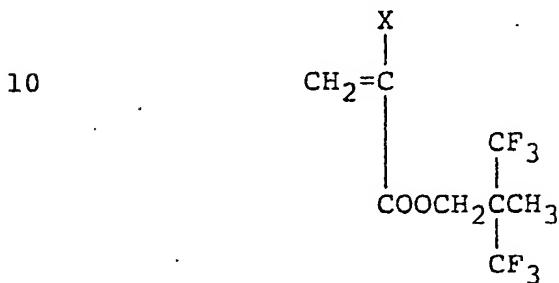
The coat thus formed was checked for adhesion to result in 0/100 by only one peeling trial of the adhesive tape.

## CLAIMS:

1. Hexafluoroneopentyl alcohol represented by the formula



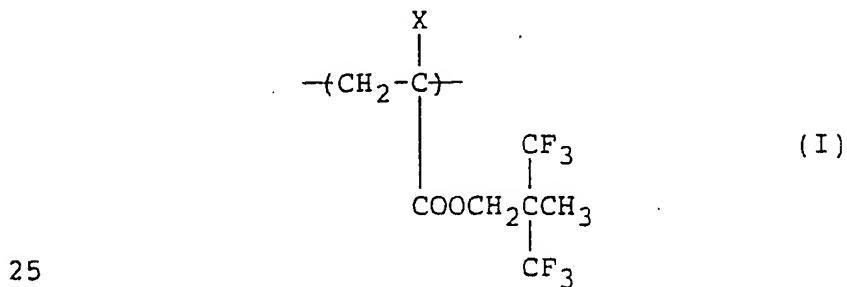
2. A hexafluoroneopentyl (meth)acrylate represented by the formula



wherein X represents hydrogen atom, fluorine atom, chlorine atom, bromine atom, iodine atom or methyl group.

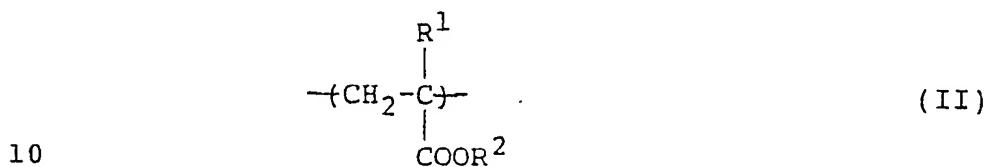
15 3. A hexafluoroneopentyl (meth)acrylate according to claim 2 wherein X is fluorine atom or methyl group.

20 4. A fluorine-containing polymer comprising a structural unit represented by the formula



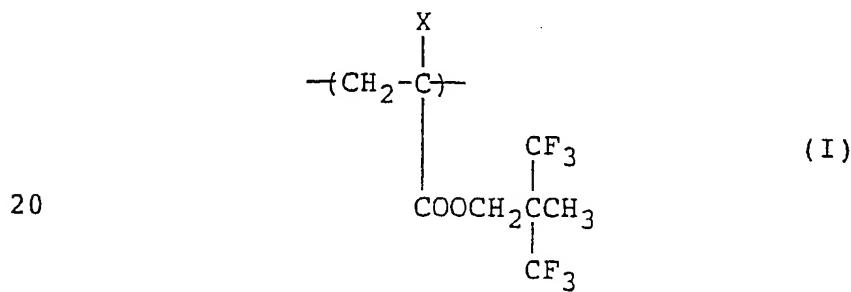
wherein X represents hydrogen atom, fluorine atom, chlorine atom, bromine atom, iodine atom or methyl group.

5. A fluorine-containing polymer according to claim 5 which comprises 10 to 99.9% by weight of the structural unit represented by the formula (I) and 0.1 to 90% by weight of the structural unit represented by the formula



wherein  $\text{R}^1$  represents hydrogen atom, fluorine atom or methyl group, and  $\text{R}^2$  represents hydrogen atom, lower alkyl group or fluoroalkyl group.

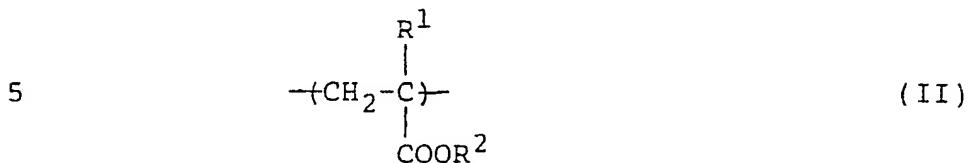
6. An optical material comprising a fluorine-containing polymer comprising a structural unit represented by the formula



wherein  $\text{R}^1$  represents hydrogen atom, fluorine atom, chlorine atom, bromine atom, iodine atom or methyl group.

7. An optical material according to claim 6 which comprises a fluorine-containing polymer comprising

10 to 99.9% by weight of the structural unit represented by the formula (I) and 0.1 to 90% by weight of the structural unit represented by the formula



wherein  $\text{R}^1$  represents hydrogen atom, fluorine atom or methyl group, and  $\text{R}^2$  represents hydrogen atom, lower alkyl group or fluoroalkyl group.

# INTERNATIONAL SEARCH REPORT

International Application No PCT/JP88/01228

## I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) <sup>6</sup>

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl <sup>4</sup> C07C31/38, 29/14, 69/653, 67/03,  
C08F20/22

## II. FIELDS SEARCHED

Minimum Documentation Searched <sup>7</sup>

Classification System	Classification Symbols
IPC	C07C29/132-29/14, 31/34-31/44, 69/62-69/657, 67/03, C08F20/00-20/70, 22/00-22/40

Documentation Searched other than Minimum Documentation  
to the Extent that such Documents are Included in the Fields Searched <sup>8</sup>

## III. DOCUMENTS CONSIDERED TO BE RELEVANT <sup>9</sup>

Category <sup>10</sup>	Citation of Document, <sup>11</sup> with indication, where appropriate, of the relevant passages <sup>12</sup>	Relevant to Claim No. <sup>13</sup>
X	JP, Bl, 47-42812 (Farbenfabriken Bayer A.G.) 28 October 1972 (28. 10. 72) & DE, A, 1,300,539 & CA, A, 849,020 & GB, A, 1,213,558	1
X	JP, Bl, 43-8978 (E.I. DuPont de Nemours and Co.) 11 April 1968 (11. 04. 68)	2-7
X	JP, A, 49-129545 (Mitsubishi Rayon Co., Ltd.) 11 December 1974 (11. 12. 74) (Family: none)	2-7
X	JP, B2, 56-8321 (Mitsubishi Rayon Co., Ltd.) 23 February 1981 (23. 02. 81) (Family: none)	2-7
X	JP, B2, 56-8322 (Mitsubishi Rayon Co., Ltd.) 23 February 1981 (23. 02. 81) (Family: none)	2-7

<sup>10</sup> Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"Z" document member of the same patent family

## IV. CERTIFICATION

Date of the Actual Completion of the International Search

February 15, 1989 (15. 02. 89)

Date of Mailing of this International Search Report

March 6, 1989 (06. 03. 89)

International Searching Authority

Japanese Patent Office

Signature of Authorized Officer

## FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

X	JP, B2, 56-8323 (Mitsubishi Rayon Co., Ltd.) 23 February 1981 (23. 02. 81) (Family: none)	2-7
X	JP, A, 56-118408 (Toyo Contact Lens Kabushiki Kaisha) 17 September 1981 (17. 09. 81) (Family: none)	2-7
X	JP, A, 58-171405 (Mitsubishi Rayon Co., Ltd.) 8 October 1983 (08. 10. 83) (Family: none)	2-7

V.  OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE <sup>1</sup>

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1.  Claim numbers ..... because they relate to subject matter not required to be searched by this Authority, namely:

2.  Claim numbers ..... because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3.  Claim numbers ..... because they are dependent claims and are not drafted in accordance with the second and third sentences of PCT Rule 6.4(a).

VI.  OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING <sup>2</sup>

This International Searching Authority found multiple inventions in this international application as follows:

Claim 1 relates to hexafluoroneopentyl alcohol, whereas claims 2 to 7 relate to fluorinated polymers, their monomers, and preparation and uses of the polymers. Therefore, they do not constitute a group of inventions so correlated as to form a single inventive conception.

1.  As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2.  As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3.  No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4.  As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

## Remark on Protest

- The additional search fees were accompanied by applicant's protest.
- No protest accompanied the payment of additional search fees.

## FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

X	JP, A, 59-21648 (Sagami Chemical Research Center) 3 February 1984 (03. 02. 84) (Family: none)	2-7
X	JP, A, 59-129208 (Mitsubishi Rayon Co., Ltd.) 25 July 1984 (25. 07. 84) (Family: none)	2-7
X	JP, A, 59-227908 (Daikin Industries, Ltd.) 21 December 1984 (21. 12. 84) & JP, A, 59-228604 & EP, A, 128,516 & US, A, 4,720,166	2-7

V.  OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE <sup>1</sup>

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3.  Claim numbers ..... , because they are dependent claims and are not drafted in accordance with the second and third sentences of PCT Rule 6.4(a).

VI.  OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING <sup>2</sup>

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3.  No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

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## Remark on Protest

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- No protest accompanied the payment of additional search fees.

## FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

X	JP, A, 60-191447 (Matsushita Electric Works, Ltd.) 28 September 1985 (28. 09. 85) (Family: none)	2-7
X	JP, B1, 43-20466 (Daikin Industries, Ltd.) 2 September 1968 (02. 09. 68) & US, A, 3457247	2-7
X	JP, A, 57-89753 (Daikin Industries, Ltd.) 4 June 1982 (04. 06. 82)	2-7

V.  OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1.  Claim numbers ..... because they relate to subject matter not required to be searched by this Authority, namely:

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## Remark on Protest

The additional search fees were accompanied by applicant's protest.  
 No protest accompanied the payment of additional search fees.

## FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

& JP, A, 58-5734 & JP, A, 58-5735  
 & EP, A, 49,884 & US, A, 4,382,985  
 & US, A, 4,421,842 & US, A, 4,421,843  
 & EP, B, 49,884

V.  OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE <sup>1</sup>

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1.  Claim numbers ...., because they relate to subject matter not required to be searched by this Authority, namely:

2.  Claim numbers ...., because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3.  Claim numbers ...., because they are dependent claims and are not drafted in accordance with the second and third sentences of PCT Rule 6.4(a).

VI.  OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING <sup>2</sup>

This International Searching Authority found multiple inventions in this international application as follows:

1.  As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2.  As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3.  No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4.  As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

## Remark on Protest

- The additional search fees were accompanied by applicant's protest.
- No protest accompanied the payment of additional search fees.